Process and Apparatus for Recycling of PET-Material

The invention relates to a process and an apparatus for recycling of PET-material according to the introductory part of claim 1 or according to the introductory part of claim 16, respectively.

Under PET-material (material of polyethylene terephthalate) all PET-materials and/or PET-objects are to be understood, also those of BOPET (bi-oriented PET), in particular pieces, milled bottle material, foils, fibers, flakes and the like.

When recycling articles of polyethylene terephthalate or of polyethylene terephthalate-materials it is of importance that the PET-material to be recycled is as dry as possible in order to avoid a hydrolytic degradation of the molecule chains by the influence of hydrogen during plastifying or during the melting step. However, an efficient drying is possible only at elevated temperature at which the amorphous PET-particles or PET-parts adhere to each other. By these reasons, a crystallization of the PET-material should be obtained before drying. Such a crystallization can be obtained by uniformly moving or mechanically treating the particles at a temperature lower than the drying temperature, in any case at a temperature that is lower than the plastifying temperature.

However, since the PET-materials to be recycled or the articles consisting of PET, in particular PET-bottles, are mostly soiled and are washed and possibly previously comminuted, at which procedure a simultaneous soiling frequently cannot be avoided, in the most cases the material is discretely comminuted or milled, washed and dried. Such a pre-drying should be at least so efficient, that the moisture content does not exceed a value of 1.5 weight-% of the PET-material to be treated or to by recycled.

In particular, it is an object of the invention to provide for a process and an apparatus of the initially described kind by which PET-material is subjected to a quick recycling that is as much power saving as possible, wherein the PET-granulate produced from the melt obtained, or PET-particles made therefrom, have high viscosity-values, in particular a viscosity that can be compared with the viscosity values of the PET-material to be recycled. Further, the obtained melt or, respectively, the PET-granulate produced from the melt should meet the rules concerning food stuff techniques, that means that harmful substances or contaminations contained in the PET-material that is supplied to the recycling process, are eliminated as far as possible by a suitable treatment.

This object is achieved within a process of the initially named kind by the features stated in the characterizing part of claim 1. An inventive apparatus of the initially described kind is characterized by the features stated in the characterizing part of claim 16.

Therefore, a two-step treatment of the delivered our supplied PET-material is made, wherein, when pre-treating in a pre-treatment apparatus, no plastification of the PET-material is made, however a crystallization and a certain pre-densification at a simultaneous drying takes place. The pre-densification is obtained by a suitable

temperature by mechanical treatment of the PET-material or by power introduction into it. In particular, increasing or controlling of the temperature is made by the mechanical treatment of the PET-material or, respectively, by conversion of the rotational energy of at least one revolving mixing and/or comminuting element into thermic energy by reasons of the friction losses occurring.

During the main treatment in a main treatment apparatus, the PET-material is further dried and crystallized at an elevated temperature and is kept under a high vacuum for a certain mean dwell time. Again there is made a mechanical treatment or material condensation and introduction of power by at least one revolving mixing and/or comminuting element that by its rotation introduces the corresponding thermic energy into the PET-material and further heats it.

The main treatment that is effected under vacuum, reduces the remaining humidity to a pre-determined defined mean value and has also the effect that volatile harmful substances are separated from the PET-material.

The temperature at the main treatment is kept below the melting temperature of the PET-material; in particular about 40 to 60°C below the melting temperature. However it is desired to keep this temperature as high as possible.

Only after the main treatment, the PET-material conveyed off is plasticized by an extruder that preferably is directly connected to the main treatment apparatus. By the direct, vacuum-tight connection, the vacuum within the main treatment apparatus can act into the inlet section of the extruder. This extruder comprises a plasticising zone followed by a compression and damming zone. This damming zone is followed by a degassing or evacuating zone in which volatile substances are sucked off from the melt by a vacuum, in particular by a high vacuum. Within this, a one-step or multi-step degassing can be provided. It is also possible to provide a plurality of compression zones and de-compression zones having different values of the vacuum one behind the other. Thereby also persistent contaminations or those which are difficult to vaporize can be vaporized off.

By a suitable selection of the temperatures and of the dwell times within the pre-treatment apparatus and within the main treatment apparatus, the viscosity value of the melt obtained from the extruder and of the PET-granulate produced from the melt can be adjusted. By suitably long dwell times and suitably high temperatures within the vacuum, a positive influence onto the viscosity is effected or, respectively, a re-polymerization takes place.

Advantageous embodiments of the invention can be seen from the following description, the claims and the drawing. In the drawing, two exemplative embodiments of the invention are nearer shown.

Fig. 1 shows an embodiment of the invention in which the PET-material is directly supplied from the pre-treatment apparatus to the main treatment apparatus. Fig. 2 shows

an embodiment of the invention in which the PET-material is supplied from the pre-treatment apparatus to the main treatment apparatus via an intermediate storage means.

PET to be recycled, in particular PET-material and/or objects of PET, can be comminuted within a comminuting unit 1 and can be supplied via a washing unit 2 to a unit 14 for pre-drying. Used PET-bottles and PET-containers to be recycled are in an advantageous manner pre-sorted and are pre-milled to an average size of about 15 to 25 mm. The residual humidity of this milled, washed and dried PET-material should be as less as possible by reasons of process technology and should amount to 1.5 % by weight maximally.

For the pre-treatment, the PET-material is supplied to a pre-processing apparatus 3 for pre-drying, in which it can be also comminuted, if desired. Within the pre-processing apparatus 3 a heating and a crystallization of the material takes place simultaneously with drying. For this, within the pre-treatment apparatus 3 a rotating mixing and/or comminuting element 5 is provided that rotates with a circumferential speed of 9 to 15 m/s. Thereby it is ensured, that the mechanic motor power is converted into heat by friction between the mixing tools and the PET-pieces or the PET-material. The throughput of the PET-material is so controlled that its average dwell-time amounts to about 35 to 65 min, preferably 40 to 60 min. Within this, the temperature of the PET-material is adjusted to about 140 to 190°C, preferably 150 to 160°C. At this temperature, the surface water evaporates immediately and due to the long dwell-time also a substantial portion of the absorbed humidity or other absorbed contamination emigrates. It is not absolutely necessary, however of advantage, if processing of the PET-material within the pre-processing apparatus 3 is made under vacuum. Thereby, the dwell-time of the PET-material within the pre-processing apparatus 3 can be decreased, or, respectively, the volume of this apparatus can be correspondingly reduced. Such processing in particular is then justified if the material to be processed should be highly protected against oxidation, or, respectively, if comminuting within the pre-processing unit 3 is not necessary.

From the pre-treatment apparatus 3, to which the PET-material is supplied, preferably continuously, in particular by a supplying unit 18, for example a conveyor belt, the PET-material is conveyed off by a conveyor unit 7, in particular a conveyor screw. It can be conveyed directly (Fig. 1) or via an intermediate storage means 6 (Fig. 2) and via a further conveyor unit, for example a conveyor screw 17, to a main processing apparatus 4.

Preferably, the main processing apparatus 4 is supplied with heated PET-material.

The conveyor unit 7 is filled by the pre-processing apparatus 3 and is kept at a temperature of 140 to 170°C, in particular 150 to 160°C.

Within the main processing apparatus 4, the particles of PET-material, which partially loosely adhere to each other, are mainly broken to pieces by a rotating mixing and/or comminuting element 5', and the temperature of the synthetic plastic material is

increased to 170 to 210°C, in particular 180 to 210°C. The circumferential speed of the mixing and/or comminuting element 5' corresponds substantially to the circumferential speed of the mixing and/or comminuting element 5 within the pre-processing apparatus 3 and also amounts to about 9 to 15 m/s.

The volume of the receptacle of the main processing device 4 and the throughput of the material are so chosen that an average dwell-time for the PET-material of 40 to 90 min, in particular 50 to 90 min is obtained. The pressure within the main processing apparatus 4 is adjusted to a value of less than 20 mbar, preferably, for obtaining best results, to less than 10 mbar.

Filling of the main processing apparatus 4 can be made directly by means of the screw 7 or by means of a sluice device 15, that operates with two gas-tight or vacuum-tight slide gates 15' and thus introduces the PET-material in batch quantities. A vacuum pump 16 is connected to the main processing apparatus 4.

An extruder 8 is connected to the main processing apparatus 4 and further processes the PET-material delivered from the main processing device 4. Within the extruder 8, the PET-material is plasticized or molten. The extruder 8 may comprise at least one degassing-zone 9, whereby a vacuum pump 10 is connected to the degassing opening in the extruder housing in order to adjust a pressure of less than 10 mbar, in particular less than 5 mbar. By providing at least one degassing zone and, if desired, applying vacuum, the separation of humidity and/or other separation products can be influenced. Preferably, the extruder 8 comprises a double degassing zone.

It has been shown that if the above mentioned processing parameters are observed, a viscosity value of the molten PET-material or of the PET-granulate could be obtained that was about 5 % above the viscosity values of the supplied PET-material. This viscosity increase could be obtained in particular by the two-step-processing as well as by the corresponding adjustment of temperature, dwell-times, vacuum pressures and number of vacuum-zones or degassing zones. It has further been shown that beside of the humidity also other separation products could be separated within the extruder by suitably adjusting temperature, pressure, dwell-times and shearing.

Within a preferred embodiment of the invention, the extruder 8 is connected gas-tightly to the main processing apparatus 4 so that the vacuum of the main processing apparatus 4 acts into the extruder inlet.

A screening or filtration device 11 may be connected to the extruder 8 and the melt passing through it is supplied to a device 12 for the production of PET-granulate. Between the extruder 8 and the filtration device 11 a device 13 for measuring the viscosity of the obtained melt can be disposed.

It is of advantage, if the PET-material is conveyed from the pre-processing apparatus 3 to the main processing apparatus 4 under exclusion of air in order to exclude that the pre-dried PET-material is moistened again.

In order to avoid that the vacuum applied to the extruder 8, in particular within the degassing-zones, acts back to the main processing apparatus 4, provisions are to be made that the compression within the extruder 8, or the tightening action of the material conveyed by the extruder are so great that any reaction of the vacuum to the main processing device 4 is avoided. The same holds for a reaction of the vacuum of the main processing apparatus 4 to the pre-processing apparatus 3. In this case, however, a reaction can be excluded by providing the sluice with suitable sluice sliding gates 15'. If the pre-processing apparatus 4 is directly connected to the main processing apparatus 4, the conveying screw must be vacuum-tight.

When supplying to the main processing apparatus 4, the supplied PET-material is within the sluice that is pre-disposed with respect to the main processing apparatus 4, already subjected to the vacuum so that no substantial pressure decrease can take place within the main processing apparatus 4. This is of advantage because the amount of the vacuum has a direct influence on the separation of the harmful substances and on the viscosity.

When an intermediate storage means 6 (Fig. 2) is used, an irregular supply of the pre-processing apparatus 3 can be tolerated.

Mostly it is sufficient to obtain the temperature increase of the supplied PET-material within the pre-processing device 3 and within the main processing device 4 by the introduction of power by means of the rotating mixing and/or comminuting elements 5, 5'. In addition, the pre-processing device 3 and/or the main processing device 4 may also be heated.

In the course of the pre-treatment and of the main-treatment, the PET-material can also be comminuted, the mixing and/or comminuting elements have then to be correspondingly constructed.

The drive means for the mixing and/or comminuting elements 5, 5' or, respectively, for the conveyor means 7, 17 or, respectively, for the extruder 8 are not shown or have been designated by M, respectively.